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Relationship of Walleye Fingerling Density and Electrofishing Catch Per Effort in Northern Wisconsin Lakes

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ABSTRACT

Investigations conducted on 13 northern Wisconsin lakes over a seven year period revealed a significant positive linear relationship between walleye fingerling catch per effort by electrofishing and fingerling density (both in number per acre and number per mile of shoreline). The best formula for describing fingerling density (number per acre) was: Y = 0.234 X, where Y = fingerling density and X = fingerling catch per mile of shoreline with an electroshocker (catch per effort). Electrofishing efficiency was negatively correlated with lake surface area and shoreline length. Efficiency was not related to conductivity, shoreline development factor, fingerling CPE or fingerling density. The mean total length of native walleye fingerlings was not related to fingerling density or lake conductivity.

CONTENTS

INTRODUCTION

Increased job diversity and size of the workload assigned to fish managers makes assessing the fisheries within their jurisdiction difficult. Therefore, field effort in achieving evaluations and making decisions at a specified level of accuracy must be efficient.

Over the last few years, available data has been assembled on the relationship of walleye (Stizostedion v. vitreum) fingerling density and catch per effort from electrofishing in late summer and fall. The data were collected by those named in the acknowledgements and the author.

This study's purpose was to examine the feasibility of developing a model to estimate walleye fingerling density from electrofishing catch per effort (CPE) data. A good correlation between these parameters would reduce the effort required to quantify walleye fingerling populations.

DESCRIPTION OF THE STUDY LAKES

The following lakes were studied: Arrowhead, Bearskin, Big Crooked, Big St. Germain, Bullhead, Butternut, Escanaba, Gilmore, Johnson, Pike, Pike-Round, Round, Shell and Sparkling. All but two of the lakes are north of Wisconsin State Highway 70, and all but one are north of Wisconsin State Highway 8 (latitude of both between 45° 30'N and 46°N). Lake surface areas ranged from 67.0 to 2,576.0 acres. Shoreline length varied from 1.3 to 6.0 miles and shoreline development factors (SDF) varied from 1.1 to 2.6. Alkalinity ranged from 11.0 to 143.0 ppm and specific conductance ranged from 24.0 to 329.0 mmhos/cm at 77F (Table 1).

TABLE 1. Morphological and chemical characteristics of the study lakes.

Lake	County	Surface Area (ac)	Shoreline Length (mi)	SDF*	Alkalinity** (ppm)	Conductivity (mmhos @ 77 F)
Arrowhead	Vilas	99	1.9	1.4	38	99
Bearskin	Oneida	384	5.9	2.1	43	87
Big Crooked	Vilas	682	5.0	1.4	13	37
Big St. Germain	Vilas	1,617	7.6	1.3	37	83
Bullhead	Manitowoc	67	1.3	1.1	143	329
Butternut	Price	1,006	11.2	2.5	29	77
Escanaba	Vilas	293	5.1	2.1	16	46
Gilmore	Oneida	301	4.7	1.9	36	59
Johnson	Vilas	78	2.3	1.8	45	98
Pike	Price	806	10.9	2.3	20	55
Pike-Round	Price	1,532	16.0	2.9	23	60 (mean of Pike & Round)
Round	Price	726	5.1	1.3	25	64
Shell	Washburn	2,576	10.2	1.4	11	24
Sparkling	Vilas	127	2.3	1.5	42	92

*SDF - shoreline development factor ($SDF = \frac{7.14 \times SL}{\sqrt{A}}$, where A = surface area to nearest acre and SL = shoreline length to nearest 0.1 mile).

**methyl purple alkalinity - Shell and Gilmore; total alkalinity - Bullhead, Escanaba, Big Crooked, Bearskin, Butternut, Pike and Round; methyl orange alkalinity - Sparkling, Big St. Germain, Arrowhead and Johnson.

METHODS

Capture Procedure

All but one study lake was electrofished with a 230-volt AC boom shocker after dark sometime between mid-September and late October. The shocker was equipped with transformers to increase the amperage if necessary (Novotny and Priegel, 1974). Bullhead Lake was an exception. Here electrofishing was conducted with pulsed DC current operating at 200 volts, 7 amps and 40 to 80 pulses per second. Two men dipnetted the stunned walleye fingerlings except at Escanaba Lake where one man netted. Escanaba Lake data was not excluded from the analysis because it was felt that the year-classes for the three years (1975, 1976 and 1978) were small enough for one man to effectively capture most of the stunned fingerlings. Escanaba Lake data for the 1977 year-class was omitted however, because it was a large year-class and many fingerlings were missed (J. J. Kempinger personal communication).

In most lakes, fingerling walleyes were the only size and species collected, however, in Pike, Round and Butternut Lakes, all stunned walleyes were captured. In Bullhead Lake, walleyes and muskellunge were captured and in Shell Lake all gamefishes were dipnetted. In each of these lakes, walleyes were the most abundant gamefish species observed and collected, and the majority of those seen were fingerlings. All were native walleye fingerling populations except in Arrowhead and Johnson Lakes, where most of the fingerlings were stocked (marked) fish.

Data were obtained by more than one crew using different electrofishing boats and probably working at various speeds. Therefore, fingerling density was compared with number of fingerlings caught per mile of shoreline rather than number captured per hour of electrofishing. An average speed for the electrofishing sampling boat was approximately 1.5 miles per hour. The data from Big Crooked, Sparkling, Bearskin, Gilmore, Arrowhead and Johnson Lakes could, therefore, be converted from catch per mile of shoreline to catch per hour. The entire shoreline of all but two of the lakes was electrofished on the first night of collecting. In Big St. Germain Lake, one-half the shoreline was electrofished the first night of the marking period and one-half the second night. The catch per effort for the first run was calculated by dividing the combined catch on these two nights by total shoreline length. In Shell Lake, the catch per effort on the first run was determined from approximately 90.0 percent of the shoreline (9.0 miles) because rough water prohibited shocking the remaining shoreline.

Data Analysis

In each study, the number of fingerlings captured per mile of shoreline (CPE) was determined for the first night of electrofishing. A mark-recapture estimate of the number of walleye fingerlings was made using either Bailey's Modification of the Petersen Method or the Schnabel Method (Ricker, 1975). In all the studies, each sampling was at least 24 hours after the time of the previous capture. Cross and Stott (1975) reported that: 1) mark-recapture population estimates using electrofishing gear should not normally be affected by a decrease in availability if the subsequent recapture period is 24 hours after the previous marking period, and 2) marked fish do not seem to become less catchable after being electrofished.

Because it was assumed that most walleye fingerlings were concentrated along the shoreline during the sampling periods (rather than equally distributed over the entire lake), the estimated density was determined for both number per mile of shoreline and number per acre.

A correlation matrix was constructed to determine which of the following factors were significantly related: 1) estimated number of fingerlings per surface acre; 2) estimated number of fingerlings per mile of shoreline; 3) fingerling CPE; 4) lake surface area; 5) shoreline length; 6) shoreline development factor; 7) conductivity and 8) alkalinity.

To reduce the influence of any one lake on the model used to predict fingerling density, averages of the above-mentioned parameters were used instead of individual values when a lake was sampled more than once. Pike and Round Lakes, which are connected by a short channel, were included as separate lakes in 1977 (when an estimate was done on each individual lake) and as one lake in 1972 (when a single estimate was done for both lakes combined).

Stepwise multiple regression analysis (Snedecor and Cochrane, 1967) was applied to the data set using both number of walleye fingerlings per mile of shoreline and number of walleye fingerlings per surface acre as the dependent variable. Models best estimating these parameters were developed. The accuracy of the models was determined by comparing the actual values with numbers predicted using the model and the R^2 value for the model.

First-run efficiencies (i.e., the percentage of the estimated population captured on the first run) were calculated for walleye fingerlings in each lake and a mean efficiency for all lakes was determined. The effect of various parameters on percent efficiency was investigated by regression analysis.

The relationship between the mean length of fingerlings captured at approximately the same time of year in lakes north of Wisconsin State Highway 8 and 1) mark-recapture estimated fingerling density and 2) water conductivity was also determined.

RESULTS AND DISCUSSION

Walleye fingerling CPE on the first electrofishing run varied from 6.4 to 131.1 per mile of shoreline while mark-recapture estimated fingerling densities varied from 0.8 to 31.8 per acre and 27.0 to 4925.0 per mile of shoreline, respectively (Table 2). Mean fingerling densities for 21 separate estimates conducted on 14 lakes over a seven year period were 10.6 per acre and 1,094.0 per mile of shoreline, respectively.

The correlation matrix calculated for two factors at a time (simple correlation) for all the variables investigated is shown in Table 3. For the sample size used to construct the matrix (n=14, df=12), the 0.05 significance level for the correlation coefficient (r) is $\pm$ 0.532. Significant relationships were found between the following parameters: 1) estimated number of fingerlings per mile of shoreline and estimated number of fingerlings per surface acre (r = 0.784); 2) fingerling CPE and estimated number of fingerlings per surface acre (r = 0.943); 3) fingerling CPE and estimated number of fingerlings per mile of shoreline (r = 0.843); 4) lake surface area and estimated number of fingerlings per mile of shoreline (r = 0.593); 5) shoreline length and lake surface area (r = 0.827); 6) shoreline development factor and estimated number of fingerlings per surface acre (r = -0.588); 7) shoreline development factor and fingerling CPE (r = -0.607); 8) shoreline development factor and lake shoreline length (r = 0.710); and 9) total alkalinity and conductivity (r = 0.991).

TABLE 2. Fingerling walleye CPE and estimated density in the study lakes.

Lake	Year	Fingerling CPE on First Electrofishing Run (catch/mi of shoreline)	Mark-Recapture Fingerling Population Estimate*	95% CI	Mark-Recapture Estimated Fingerling Density (no/acre)	Mark-Recapture Estimated Fingerling Density (no/mi of shoreline)
Arrowhead	1978	43.2	1,049	911-1,346	10.6	552.1
Bearskin	1975	62.0	5,722	4,109-7,334	14.9	969.8
	1976	23.7	2,266	1,843-3,072	5.9	384.1
Big Crooked	1974	22.4	5,265	3,001-12,685	8.2	1,053.0
Big St. Germain	1976	35.6	12,804	809-31,370	7.9	1,684.7
	1978	48.9	17,431	4,528-30,400	10.8	2,293.6
Bullhead	1976	79.5	1,620	697-2,546	24.2	1,246.2
Butternut	1973	10.9	2,213	***	2.2	197.6
Escanaba	1975	42.0	1,963	1,787-2,139	6.7	384.9
	1976	75.1	2,344	1,465-2,930	8.0	459.6
	1978	68.0	5,333	4,864-6,505	18.2	1,045.7
Gilmore	1977	26.6	963	391-1,994	3.2	204.9
Johnson	1978	4.8	62	31-203	0.8	27.0
Pike	1977	16.9	7,012	***	8.7	643.3
Pike-Round**	1972	6.4	3,524	***	2.3	220.3
Round	1977	131.1	23,087	***	31.8	4,526.9
Shell	1977	96.6	50,238	31,170-62,082	19.5	4,925.3
Sparkling	1975	56.1	1,092	648-1,537	8.6	474.8
	1976	82.6	2,591	2,400-267	20.4	1,126.5
	1977	16.5	330	229-749	2.6	143.5
	1978	67.8	927	889-1,270	7.3	403.0

* Fingerling populations were estimated by Bailey's Modifications of the Petersen Method in Pike-Round, Butternut, Big St. Germain, Pike, Round, Shell, Bullhead and Gilmore Lakes and by the Schnabel Method in Big Crooked, Sparkling, Bearskin, Escanaba, Arrowhead and Johnson Lakes.

** In 1972, Pike and Round Lakes, which are connected, were worked as one lake instead of making a separate estimate for each lake.

*** Estimates of walleye fingerlings in Pike, Round and Butternut Lakes were determined by dividing the population estimates of walleyes age 0 and older by the reciprocal of the percentage of a sample of measured walleyes that were fingerlings. Therefore, no confidence intervals could be calculated for these estimates.

TABLE 3. Correlation (r)* matrix of the variables investigated for the study lakes.

Variable No. and Name	1 Estimated No Fingerlings/ Surface Area	2 Estimated No Fingerlings/ Mi of Shore	3 Fingerling CPE (catch/ mi of shore)	4 Lake Surface Area (acres)	5 Lake Shoreline Length (miles)	6 Shoreline Development Factor (SDF)	7 Conduct. (µmhos/ cm @ 77F)	8 Total Alkalinity (ppm)
1) Estimated no fingerlings/ surface acre	1.000							
2) Estimated no fingerlings/ mi of shore	0.784	1.000						
3) Fingerling CPE (catch/mi of shoreline)	0.943	0.843	1.000					
4) Lake surface area (ac)	0.086	0.593	0.147	1.000				
5) Lake shoreline length (mi)	-0.271	0.082	-0.285	0.827	1.000			
6) Shoreline development factor (SDF)	-0.588	-0.485	-0.607	0.099	0.710	1.000		
7) Conduct. (mmhos/ cm @ 77F)	-0.334	-0.144	-0.159	-0.416	-0.480	-0.367	1.000	
8) Total alkalinity (ppm)	-0.306	-0.153	0.150	-0.428	-0.451	-0.382	0.991	1.000

*Tabular r value for $P \leq 0.05$ and 12 d.f. is $\pm$ 0.532; r for $P \leq 0.01$ is $\pm$ 0.661.

The model best describing the estimated number of fingerlings per mile of shoreline (Y) was Y = 27.885 (fingerling CPE) + 1.074 (lake surface area in acres) - 441.229 (SDF). The coefficient of determination (R^2) for this model was 0.957 indicating that 95.7 percent of the variance in the number of fingerlings per mile of shoreline was explained by differences in fingerling CPE, lake surface area and SDF. The estimated number of walleye fingerlings per surface acre (Y) was best described by the model: Y = 0.211 (fingerling CPE) + 0.018 (conductivity). The coefficient of determination (R^2) for this model was 0.970, however, the data was probably influenced by Bullhead Lake, which had an extremely high conductivity and the second highest population density (when compared to the other lakes in the data set).

Another model which is simpler and probably as accurate for predicting the number of fingerlings per surface acre (Y) is: Y = 0.234 (fingerling CPE). In this model, the regression line was forced through the origin because it was assumed that when fingerling CPE was zero, fingerling density would be at or near zero. The coefficient of determination for this model was 0.957 or the same as that for the model used to predict the number of fingerlings per mile of shoreline.

Population estimates and stocking quotas are usually expressed in number per surface area instead of number per shoreline length. The coefficient of determination for the model used to predict the number of fingerlings per mile of shoreline was the same as that for the model to predict number of fingerlings per surface acre. Therefore, the most useful model for predicting fingerling density in the study lakes is: Y = 0.234 (fingerling CPE) where Y = number of fingerlings per surface acre.

The mean and standard deviation of the differences between the predicted and actual fingerling densities was 0.7 per acre and 3.7 per acre, respectively. This indicates that predicted values would be slightly higher than actual values (Table 4). The lowest percentage of variability between the predicted and actual values seemed to occur for the extremely low or high actual densities. The highest variability usually occurred in the intermediate densities. The average percent difference (sign ignored) between the predicted and actual values was 36.0 percent.

TABLE 4. Predicted* and actual** walleye fingerling densities in the study lakes.

Lake	Year	Fingerling CPE of First Electro-Fishing Run	(A) Predicted Fingerling Density (no/acre)	(B) Actual Fingerling Density (no/acre)	A-B	A-B/B (expressed as percent with sign ignored)
Arrowhead	1978	43.2	10.1	10.6	-0.5	5
Bearskin	1975	62.0	14.5	14.9	-0.4	3
	1976	23.7	5.6	5.9	-0.3	5
Big Crooked	1974	22.4	5.2	8.2	-3.0	37
Big St. Germain	1976	35.6	8.4	7.9	0.5	6
	1978	48.9	11.5	10.8	0.8	7
Bullhead	1976	79.5	18.6	24.2	-5.6	23
Butternut	1973	10.9	2.6	2.2	0.4	18
Escanaba	1975	42.0	9.8	6.7	3.1	46
	1976	75.1	17.6	8.0	9.6	120
	1977	68.0	15.9	18.2	-2.3	13
Gilmore	1977	26.6	6.2	3.2	3.0	94
Johnson	1978	4.8	1.1	0.8	0.3	38
Pike	1977	16.9	3.9	8.7	-4.5	52
Pike-Round	1972	6.4	1.5	2.3	-0.8	35
Round	1977	131.1	30.6	31.8	-1.2	4
Shell	1977	96.6	22.6	19.5	3.1	16
Sparkling	1975	56.1	13.1	8.6	4.5	52
	1976	82.6	19.4	20.4	-1.0	5
	1977	16.5	3.9	2.6	1.3	50
	1978	67.8	15.9	7.3	8.6	118
***	$\overline{X}$	48.4	11.3	10.6	0.7	36
***	s	32.4	7.6	7.9	3.7	36

* Predicted (using Y = 0.234 X, where Y = fingerling density (no/acre) and X = fingerling CPE on first electrofishing run).

** Actual (mark-recapture estimated fingerling densities shown in Table 2).

***$\overline{X}$ = mean, s = standard deviation.

Walleye fingerling electrofishing efficiencies (i.e., the percentage of the mark-recapture fingerling estimate captured on the first electrofishing run) for the study lakes ranged from 2.0-17.7 percent, with a mean and standard deviation of 7.6 (±) 5.2 percent (Table 5). A significant negative curvilinear relationship existed between percent efficiency on the first run and lake surface area ($P<0.01$) and shoreline length ($P<0.01$). Percent efficiency on the first run was not significantly affected ($P>0.05$) by conductivity, shoreline development factor, fingerling CPE or fingerling density (Table 6). In a study of AC electrofishing efficiency in central United States farm ponds and reservoirs, Simpson (1978) reported that efficiency was negatively related to surface area and population density (of both largemouth bass and bluegill) and was positively correlated with catch per effort.

TABLE 5. Catch of fingerling walleyes on first run, mark-recapture population estimates and electrofishing efficiencies (%) for the study lakes.

Lake	Year	No Captured On First Run	Mark-Recapture Population Estimate	Electrofishing Efficiency (%)
Arrowhead	1978	82	1,049	7.8
Bearskin	1975	336	5,722	6.4
	1976	140	2,266	6.2
Big Crooked	1974	112	5,265	2.0
Big St. Germain	1976	271	12,804	2.1
	1978	372	17,431	2.1
Bullhead	1976	101	1,620	6.2
Butternut	1973	122	2,213	5.5
Escanaba	1975	214	1,963	10.9
	1976	383	2,344	16.3
	1978	347	5,333	6.5
Gilmore	1977	125	963	13.0
Johnson	1978	11	62	17.7
Pike	1977	183	7,012	2.6
Pike-round	1972	102	3,524	2.9
Round	1977	666	23,087	2.9
Shell	1977	985*	50,238	2.0
Sparkling	1975	129	1,092	11.8
	1976	190	2,591	7.3
	1977	38	330	11.5
	1978	156	927	16.8

Mean (± standard deviation) electrofishing efficiency = 7.6% (± 5.2).

*869 walleye fingerlings were captured while electrofishing 9.0 miles of shoreline. At this CPE of 96.6/mile of shoreline, an estimated 958 fingerlings would have been captured if the entire shoreline (10.2 miles) had been electrofished.

TABLE 6. Simple correlation coefficients (r) for the relationship between various parameters and percent efficiency on the first sampling run (y).

Independent Variable (X)	r	Signif[a]
Shoreline development factor[b]	0.087	NS
Log_{10} lake surface area (acres)	-0.800	**
Log_{10} shoreline length (miles)	-0.620	**
Conductivity	0.057	NS
Estimated fingerling density	-0.391	NS
Fingerling CPE	0.096	NS

[a] $P < 0.01$ - **
$P > 0.05$ - NS (not significant)

[b] $SDF = \frac{7.14 \times SL}{\sqrt{A}}$, where A = lake surface area in acres and SL = shoreline length in miles.

The mean total length of native walleye fingerlings collected at approximately the same time of year (early September - mid-October) in the study lakes ranged from 4.6-7.1 inches (Table 7). There was no correlation between the mean total length of fingerlings and their density ($r = 0.223$, df = 15, $P > 0.05$) and no relationship between mean length and total alkalinity ($r = 0.33$, df = 15, $P > 0.05$). This indicates that intraspecific competition for food was probably minimal in the majority of the populations studied and fingerling growth was not related to water hardness.

TABLE 7. Relationship between mark-recapture estimated density and mean total length of native walleye fingerlings in the study lakes north of Wisconsin State Highway 8.

Lake	Year	X Fingerling Density (no/ac)	Y Mean Total Length In Inches (no measured)	Total Length Range In Inches
Bearskin	1975	14.9	6.4 (112)	5.1 - 7.6
	1976	5.9	7.1 (138)	5.5 - 7.7
Big Crooked	1974	8.2	5.3 (622)	3.0 - 6.6
Big St. Germain	1976	7.9	7.1 (270)	5.6 - 7.9
Butternut	1973	2.2	5.7 (53)	4.6 - 7.0
Escanaba	1975	6.7	4.6 (208)	3.4 - 6.4
	1976	8.0	5.6 (263)	4.4 - 7.9
	1978	18.2	5.1 (177)	3.7 - 6.9
Gilmore	1977	3.2	6.2 (125)	4.9 - 7.1
Pike	1977	8.7	5.3 (34)	3.8 - 6.7
Pike-Round	1972	2.3	5.5 (54)	4.0 - 7.3
Round	1977	31.8	5.3 (26)	3.7 - 7.3
Shell	1977	19.5	5.4 (200)	
Sparkling	1975	8.6	5.6 (89)	4.0 - 6.9
	1976	20.4	5.0 (190)	3.0 - 6.5
	1977	2.6	4.7 (95)	3.3 - 6.6
	1978	15.1	4.6 (156)	3.6 - 6.2

SUMMARY AND SUGGESTIONS FOR FUTURE STUDY

Data indicate a significant positive relationship between walleye fingerling CPE and density. Coefficients of determination (R^2) for the models judged to best estimate fingerling density (both in number per acre and number per mile of shoreline) were equal (0.957). Because walleye fingerling population estimates and stocking quotas are usually quantified in number per acre rather than number per mile of shoreline, the model to estimate number per surface acre ($Y = 0.234$ fingerling CPE), where Y = number of fingerlings per surface acre would probably be most useful. The mean percent difference (sign ignored) between densities calculated using this model and the mark-recapture estimated densities was 36.0 percent.

The model developed in this investigation to estimate the number of fingerlings per surface acre should be used with caution when estimating fingerling densities in lakes other than those included in this study. The model may be less accurate when applied to fingerling populations and water bodies with values outside the range of those included in this analysis. Further studies of the relationship of electrofishing catch per effort and estimated fingerling density in lakes with physical and chemical characteristics different than those for lakes included in this analysis are needed to test the model's flexibility.

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